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Disease-a-Month

Chronic Arterial Insufficiency of the Lower Extremities

MICHAEL E. DEBAKEY
E. STANLEY CRAWFORD
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Chronic Arterial Insufficiency of the Lower Extremities

MICHAEL E. DEBAKEY
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CHRONIC ARTERIAL INSUFFICIENCY of the lower extremities is a rather broad term which signifies simply a diminution in the normal amount of circulating blood to the parts. It is usually produced by a decrease in the normal caliber of the arterial tree, and this diminished intraluminary volume may be produced by a number of different pathologic states which in general may be classified into two categories, namely, vasomotor disturbances and obliterative structural changes. The former group is exemplified by such conditions

as Raynaud's disease, acrocyanosis and other primary or secondary vasospastic disorders in which the primary disturbance, at least in the early stages of the disease, is an abnormal spasm of the vessel wall causing constriction and reduction in lumen size. The second category is exemplified by such conditions as arteriosclerosis obliterans, thromboangiitis obliterans (Buerger's disease) and various forms of arteritis in which the primary disturbance consists of structural changes in the vessel wall which cause reduction in size of the lumen or completely occlude it. This presentation is concerned with one of the latter group, arteriosclerotic occlusive disease, which in terms of incidence and morbidity constitutes the most common and important form of chronic arterial insufficiency of the lower extremities and consequently deserves the most serious consideration.

Until relatively recently the prevailing attitude characterizing the therapeutic approach to this problem was almost fatalistic. This was due in large measure to earlier concepts that arteriosclerosis is an inevitable consequence of aging, and therefore an irreversible process, and to the general belief that the disease is widespread and diffusely involves the major arterial channels. Accordingly, previous efforts to change the natural course of the disease consisted of indirect measures designed to limit the need for circulation and to obtain maximum blood flow through the collateral bed. This regimen of limited activity, combined with vascular exercises and the use of vasodilators and lumbar sympathectomy, was admittedly beneficial but only rarely completely relieved symptoms and too frequently failed to avert amputation.

In recent years a much more hopeful outlook in therapy has been developed as a result of certain pathologic and arteriographic studies, which have provided a better understanding of the disease, leading to more rational therapy with a direct attack on the occlusive lesion aimed at restoration of blood flow through the main arterial channel. It has been shown, for example, that the obstructing lesion in chronic arteriosclerotic occlusive disease of the lower extremities is frequently well localized and segmental in nature, with a relatively normal patent vessel above and below the occlusion. This fortunate pathologic feature of the disease permits direct attack on the occlusive process in re-establishing immediate arterial continuity. This possibility became a reality with the development of thromboendarterectomy by Dos Santos and

others. Unfortunately, the results from endarterectomy have been inconsistent and experience has shown that it can be applied only under certain well-defined circumstances. For this reason, other forms of therapy were developed to overcome some of these problems, including the use of excision of the obstructing segment with its replacement by a homograft or a comparable plastic tube or by means of a bypass procedure with the use of similar homografts or plastic tubes to shunt blood around the occluded segment. These methods of therapy have afforded an opportunity to study and correlate the pathologic features of the disease with clinical manifestations, diagnostic procedures and the indications for specific types of surgical treatment as well as their efficacy. Accordingly, this report is concerned with certain observations derived from an analysis of our experience with 436 cases treated by these direct surgical methods.

INCIDENCE

Arteriosclerotic occlusive disease of the lower extremities occurs predominantly in the male sex in the fifth to seventh decades of life. In this series only 9% were in females.

TABLE 1.—AGE INCIDENCE AND DEGREE OF OCCLUSION IN 253 CASES OF THROMBO-OBLITERATIVE DISEASE OF THE ABDOMINAL AORTA

AGE	COMPLETE	INCOMPLETE	TOTAL
20–29	2	..	2
30–39	6	5	11
40–49	30	37	67
50–59	41	72	113
60–69	19	36	55
70–79	1	3	4
80–	..	1	1
Total	99	154	253

Among the patients with diabetes, however, this difference in sex ratio was much less pronounced. In this connection, too, diabetes was most commonly encountered in the younger age group.

Approximately 90% of the cases were in the fifth, sixth and seventh decades, with the highest incidence—a little over 40% —in the sixth decade. The youngest patient was 26

and the oldest was 81. Of particular significance is the fact that the patients in this series with complete occlusion of the aorta were on the average about a decade younger than those with incomplete occlusion (Table 1).

PATHOLOGY

Arteriosclerotic disease begins with intimal proliferation and deposition of lipid material in the subintimal layer of the arterial wall. Continuing deposition of this substance and local changes in the deposit itself, such as cystic formation, calcification and foreign body reaction, result in formation of an atheroma. This lesion may be extensive, but it is more frequently localized, being only one or two centimeters in length and involving part or all the circumference of the vessel. As the atheroma enlarges, it expands toward the intima, which is elevated and thickened, and more and more of the lumen is thus consumed by the enlarging atheromatous mass. Eventually, a critical point of narrowing is reached until flow through the constriction is slowed down sufficiently to create an environment for intravascular clotting, and with the resulting thrombosis complete occlusion of the lumen takes place. Under these circumstances, clotting extends proximally until a collateral branch is reached that permits rapid and more complete egress of blood into the collateral bed, and distally until a collateral branch is reached through which sufficient blood is flowing from the collateral bed into the central artery at a rate of flow that does not allow clotting to take place. Consequently, the occlusion seen at operation or in the arteriogram frequently consists to a large extent of a thrombus in varying stages of organization. The arteriosclerotic element itself may represent only a small part of the occlusion, and the artery both above and below this region may be entirely normal.

This process of occlusion is fortunately gradual and, because of its frequently insidious nature, collateral channels are able to enlarge as the main arterial routes become progressively obstructed. As a result of this natural alteration, gangrene usually does not occur immediately on occlusion and a second characteristic pathologic finding is produced. The intraluminal thrombus, as in other organs, undergoes reorganization by fibrous tissue, and the inflammatory reaction of healing incited by the thrombus and the foreign body

reaction stimulated by the atheroma produce local arterial invasion by fibrous tissue that results in the incorporation of the involved arterial segment within dense fibrous or scar tissue. The extent of this reaction depends, of course, on the duration of the occlusion. Acute occlusions may show little or no such reactions and those of long duration may be associated with advanced changes. The terminal aorta in patients with long-standing Leriche's syndrome has occasionally been found to be largely replaced by or incorporated in dense fibrous scar tissue.

Although the disease may be variable in its pathologic features, it tends to assume certain recognizable patterns, particularly as to location and extent of the occlusive process. Accordingly, it may be classified into two broad groups, aorto-iliac occlusion and femoral occlusion. In the former type careful examination of the pathologic changes encountered in the resected specimens have fully confirmed the original observations of Leriche that the occlusive process arises in the common iliac arteries and aortic bifurcation and is often well localized to this region. The underlying lesion is predominantly one of atherosclerosis with superimposed thrombosis. The nature and extent of the pathologic process in this group suggests classification into two subgroups, those producing incomplete occlusion of the terminal aorta and those characterized by complete occlusion. In the former type of the disease, extensive atheromatous changes occur in the common iliac arteries, apparently originating at the iliac or aortic bifurcation with progressive diminution in these changes both proximally and distally. In some instances one of the common iliac arteries becomes completely occluded, the lumen being filled with pale yellow thrombi superimposed on atheromatous plaques. When both common iliac arteries become similarly involved, complete occlusion of the terminal aorta occurs and gradual propagation of the thrombotic process takes place upward to the renal arteries, and ultimately this may produce occlusion of these vessels with terminal renal failure (Fig. 1). Histologic studies of these diseased segments further support the concept that the occlusive pathologic changes arising in the aorto-iliac zone can extend by propagation of the thrombotic process to an adjacent portion of the aorta. Although it is conceivable that the partially occlusive lesions of the iliac arteries represent stages in the development of the disease toward complete aortic occlusion, certain significant differ-

FIG. 1.—Complete occlusion of the aorta distal to the renal arteries. Partial occlusion of the left renal artery at its origin and poor renal parenchymal filling is demonstrated in the left kidney.

ences have been observed in these two forms of the condition. Among these the most impressive feature has been the fact that a high proportion of the cases with complete aortic occlusion seem to have a well-localized process with the obliterative lesion confined to the terminal aorta and bifurcation and with a relatively normal patent peripheral arterial bed. On the other hand, in those with incomplete occlusion, the disease tends to be much less localized and to be more commonly associated with atherosclerotic occlusive lesions of the peripheral arterial tree.

In the second or more peripheral form of arteriosclerotic occlusive disease, the obstructive lesion is usually located in the superficial femoral artery. Here, again, some variations exist in the nature and extent of the occlusive process. It may be relatively small and only partially obstruct the lumen or it may be completely obstructive, involving virtually the entire length of the artery. It would appear to arise most frequently in the midportion of the artery lying in Hunter's canal. Most significant is the fact that it is usually segmental in character and, even when the artery is extensively involved, it is often sharply limited proximally to the origin of the profunda femoris and distally to the popliteal artery just above its bifurcation. Thus, the arterial bed is frequently patent above and below the obstruction. This, of course, is a fortunate pathologic feature of the disease, the significance of which, as will be indicated below, lies in the fact that it permits reestablishment of normal circulation in the patent arterial bed below the obstruction.

Although the disease tends to assume one of the characteristic patterns described above, there is some variation and even combination of these different types. Some patients, for example, have been found to have both complete aorto-iliac occlusion associated with segmental occlusion in one or both femoral arteries. In other instances the occlusive process may be entirely unilateral with both a high iliac and a low femoral occlusion. In still other instances the disease may extend from the aorta to the popliteal artery either unilaterally or bilaterally but with a patent peripheral arterial bed. Finally, there is the unfortunate group in which there is diffuse arteriosclerotic occlusive disease in the more peripheral vessels of the leg, precluding efforts to restore normal circulation.

The collateral circulation or alternate route of arterial blood flow also assumes certain constant patterns for each

region of occlusion, and its importance is well demonstrated by the fact that life in the extremity is maintained by blood flowing through these channels. Collateral circulation around the aorta and iliac arteries is by either or a combination of two routes. The first is systemic in which blood leaves the aorta above the occlusion by way of the lumbar, spermatic and phrenic arteries and re-enters the patent central channels below the occlusion by way of the inferior epigastric and hypogastric arteries or their branches (Fig. 2). The second route is viscero-systemic, inasmuch as blood leaves the aorta above the occlusion by way of either or both mesenteric arteries and re-enters the patent system below by way of branches of the hypogastric and external pudendal arteries (Fig. 3). As previously stated, aortic occlusions may extend by retrograde thrombosis up to the renal arteries. Approximately 25% of the cardiac output flows into the renal arteries, and consequent to this large volume and rate of flow, the renal arteries are seldom involved by retrograde thrombosis, but owing to the poor collateral blood supply of the kidneys, the renal arteries participate very little in the collateral flow around the occluded aorta. On the other hand, when renal blood flow is diminished by renal disease or arteriosclerotic narrowing at the origin of the renal artery, one or both of these vessels may become involved in the occlusive process (Fig. 1). All degrees of this involvement have been observed and hypertension and uremia, if untreated, are causes of death in a significant number of these patients.

The collateral pathways around occlusion of a superficial femoral artery originate from the profunda femoris and the muscular branches of the femoral artery above the occlusion and communicate with the popliteal artery below the occlusion (Fig. 4). The capacity of this collateral bed to maintain peripheral circulation is considerably less than that at higher levels. Size is undoubtedly the determining factor, since the diameter and volume of flow through this distal collateral bed is less, and since the diameter of the central vessel is smaller than the larger aorta and iliac arteries, occlusion is less subtle and consequently maximal collateral development does not take place prior to occlusion. A more striking difference in the collateral flow of the two regions is the difference in the participation of the distal central channels. Aortic and iliac occlusions are usually discrete and the 253 patients that we have operated on for lesions at this level have all had

FIG. 2.—*A*, complete occlusion of the aorta and common iliac arteries distal to the inferior mesenteric artery. *B*, collateral circulation around the occlusion. Proximal collateral channels consist of lumbar arteries (a′) and descending branch of left inferior phrenic artery (b′) communicating distally with the deep circumflex illiac artery (c′) and ilio-lumbar artery (d′).

FIG. 3.—*A*, complete occlusion of the left common iliac artery and partial occlusion of the terminal abdominal aorta and right common iliac artery. *B*, collateral channels from the proximal aorta. The contrast medium enters the midcolic branch of the superior mesenteric artery and is directed into the patent distal vessels below

FIG. 4.—*A*, complete and partial occlusion of the superficial femoral artery. *B*, the collateral circulation demonstrated by diagram. Blood from the common femoral artery (a′) bypasses the occlusion (c′) and reenters the patent distal artery (e′) through the deep femoral artery (b′) and its branches (d′).

FIG. 3.—*A*, complete occlusion of the left common iliac artery. *B*, collateral channels from the proximal aorta. The contrast medium inal aorta and right common iliac artery, enters the multiple branches of the internal mammary artery and is directed into the patent distal vessels below

patent distal segments of sufficient size to permit re-establishment of circulation. The popliteal, posterior tibial, anterior tibial and perineal arteries, on the other hand, are small vessels, and consequently when their lumens are narrowed the percentage of reduction in blood flow is greater than that of the proximal larger arteries and their collateral flow participation is proportionately reduced. The degree of distal involvement in the thigh can be such that a patent segment of operable size may not be found. This unfortunate situation, however, cannot be predicted on clinical grounds and arteriography is required in all lesions at this level.

CLINICAL MANIFESTATIONS

Arteriosclerotic arterial insufficiency of the lower extremities produces symptoms and physical findings that vary with the extent and duration of ischemia as well as the location of the lesion. The clinical manifestations may be mild, moderate or severe.

Mild

A small but significant number of patients complain only of a feeling of fatigue in the calves, thighs, or both, on walking a short distance. This fatigue quickly disappears after a brief pause only to return after another short walk. The sudden development of such a constant pattern of symptoms in middle-aged persons causes some patients to seek medical advice when improvement does not occur spontaneously in a few weeks or months. Other patients, particularly older ones, accept this as a sign of old age, and having been given such assurance do not seek medical attention until the disease is more advanced. This is understandable because the results on routine physical examination are often not strikingly abnormal. All peripheral pulses may be present although careful examination would reveal diminished volume. The other signs of ischemia are often absent. The diagnosis of occlusion is suspected by the inability of the muscles in the leg to tolerate any significant increased demand for arterial blood and the presence of a systolic murmur distal to the constriction; however, the presence and location of the occlusion can be determined only by arteriographic studies of the distal aorta, iliac and femoral arteries. The lesion is usually local-

Fig. 5.
mon iliac

FIG. 5.—Bilateral partial occlusions of the proximal segment of common iliac arteries.

ized, being short in length and only partially occluding the arterial lumen (Fig. 5). Such patients are ideal candidates for operation, since this well-localized, discrete, partially occluding lesion is readily corrected by any of the direct technics. Relief of symptoms and restoration to good health have been accomplished in all patients of this group.

Moderate

The largest number of patients in our series had moderately severe ischemia. This was manifested by overt intermittent claudication, loss of hair, decreased temperature of the feet and a moderate to severe degree of reduced tolerance to ambulatory activity. In 72% of our patients intermittent claudication was the major or an outstanding secondary complaint. The location of the claudication depends on the site of the lesion. If the occlusion is located in the thigh, claudication is limited to the muscles of the feet, calves or both. Higher occlusion in the iliac arteries, the abdominal aorta or both may produce claudication also in the thighs and buttocks. Pain in the lower part of the back is also frequently associated with these symptoms of higher occlusions. Because of the combination of pain in the back, thigh, leg and foot, disease within the spine or spinal canal may be suspected; a number of patients in this series had had normal lumbar myelograms performed before the true nature of the disease became apparent. Other patients have been erroneously treated for discouraging periods for arthritis. A large percentage of our male patients with the more central occlusions had sexual impotence, a symptom particularly disturbing to younger men.

The most significant finding on physical examination is the change in the peripheral pulses, and the location of the occlusion can usually be determined by this finding. In patients with complete occlusion pulses are not palpable beyond the point of obstruction except in those few patients in whom large collaterals have developed around the occlusion. With these relatively infrequent exceptions, femoral occlusions have palpable pulses in the groin but absent popliteal and pedal pulses. Unilateral iliac occlusions are associated with absent pulses throughout the involved extremity and normal pulses throughout the opposite limb. Pulses are absent throughout both lower extremities in patients with bilateral

iliac and aortic occlusions. The extent of occlusion in the latter patients can be frequently suspected on the basis of the aortic pulsations. Normally, the aortic bifurcation is near the umbilicus and the pulsations of the abdominal vessels can be frequently felt below this level when the iliac artery is involved, and when the aortic occlusion extends up to or near the renal arteries, the abdominal aortic pulsations may be difficult to find or may be present only in the epigastrium. The inferior epigastric artery, which arises in the groin, participates in the collateral circulation as previously described and in these cases it may be several times its normal size. Occasionally, pulsations in this vessel are felt in the groin and may cause the examiner to attribute these pulsations erroneously to the femoral artery; however, with experience this can be differentiated clinically. The other physical findings frequently seen in the patient with moderately severe arterial insufficiency are loss of hair on the toes, feet and lower legs, muscle atrophy, hypertrophied brittle nails and mild to moderate reduction in temperature in the feet.

Severe

Patients with ischemic changes that are pregangrenous or associated with early gangrenous lesions have severe or terminal arterial insufficiency. These patients may complain of pain at rest and cutaneous lesions about the toes or foot. These manifestations are more likely to occur in the more peripheral forms of occlusive disease. Thus, in our series of such patients 22% had rest pain and 20% had cutaneous lesions. Approximately 20% of our patients complained of a combination of these difficulties, which would ordinarily indicate the necessity for amputation according to earlier concepts of treatment. Most of these patients had had symptoms similar to those described for the moderately severe group but for a much longer period. The symptoms at rest usually were of short duration and had developed gradually in some, but in the majority of cases these symptoms developed following ordinarily insignificant trauma or infection.

Physical examination revealed absent pulses in the feet and lower legs beyond the point of obstruction, cold extremities, blanching on elevation, dependent rubor and cutaneous lesions ranging from fissuring to ulceration and gangrene. Even though most of these patients had chronic arterial

insufficiency, in some patients symptoms of acute arterial insufficiency developed suddenly and were of short duration. The etiologic diagnosis in such cases may seem difficult since embolic occlusions are thought to be more commonly associated with an acute onset. The diagnosis has been reasonably clear in our cases. Patients whose symptoms were caused by local thrombosis in an arteriosclerotic lesion have admitted on careful questioning that they had had previous mild intermittent claudication, which is to be expected in light of the natural course of the disease. Patients whose symptoms are due to embolic occlusions rarely have a history of previous difficulty in the involved extremity. Another significant differential factor is the presence or absence of a disease that may produce embolization, such as recent myocardial infarction, rheumatic heart disease, auricular fibrillation or aneurysm.

There are certain noteworthy differences in the characteristic clinical manifestations of patients with high or aorto-iliac occlusion and those with femoral or peripheral occlusive disease. For one thing, pain or distress in the hips, thighs and back constitute prominent complaints in the former group and often precede the development of symptoms in the lower legs. For another, there is relative absence of significant trophic or nutritional changes in the legs and feet in contrast with the frequency of such findings in peripheral arteriosclerosis obliterans. Still another feature encountered in the majority of the patients with high obstruction is the presence of a fairly well localized soft blowing systolic murmur usually heard best over the upper abdomen. Among patients with aorto-iliac occlusion certain differences in clinical manifestations have been observed in those with complete and in those with incomplete aortic obstruction that appear significant. Thus, hip, thigh and buttock pain occurs more commonly in the former than in the latter group. Also noteworthy is the fact that sexual impotence tends to occur predominantly in patients with complete occlusion. Still another striking feature is hypertension, which was present in about half the cases and seemed to occur most frequently in patients with complete occlusion.

DIAGNOSIS

The diagnosis of arteriosclerotic occlusive disease of the lower extremities can usually be made on the basis of the

characteristic clinical manifestations and physical findings. Of particular importance in this connection is the differentiation of this condition from thromboangiitis obliterans, since the newer and more effective forms of surgical treatment are generally not applicable to the latter condition. This is well demonstrated by arteriographic studies which were done in nine of our patients with Buerger's disease and which revealed diffuse involvement of the arterial tree distal to the popliteal artery, thus precluding application of endarterectomy and arterial graft procedures. Accordingly, this diagnosis condemns the individual to the older, less effective forms of treatment and, consequently, an accurate etiologic diagnosis is of considerable importance. The significance of this is well demonstrated by the fact that a considerable number of the patients referred to us were told that they had Buerger's disease, but in most instances they proved to have arteriosclerotic occlusions.

An accurate diagnosis can usually be made on a clinical basis. The history of trauma in traumatic lesions and the presence or history of heart disease or aneurysms in the embolic occlusions is usually adequate to establish these diagnoses. Buerger's disease is differentiated clinically from the arteriosclerotic group primarily on the basis of the age of onset. The former disease characteristically begins in the third or fourth decade of life, but rarely in the fifth decade. Arteriosclerosis, on the other hand, becomes manifest later in life, and occlusive lesions of the distal aorta, iliac and femoral arteries from this disease usually become evident after the age of 40. Even though all the older age groups may be affected, in our experience the greatest incidence has been between the ages of 40 and 70 (Table 1). Because diabetes accelerates the development of certain degenerative changes in the body, arteriosclerotic occlusion may develop earlier in patients with diabetes than in others. All our patients under 30 and most under 40 who had arteriosclerotic occlusions also had diabetes. Thus, the presence of diabetes in the younger patient with occlusive vascular disease is helpful in differentiating between arteriosclerosis and thromboangiitis obliterans.

A common source of confusion in the differentiation of the two lesions under discussion is associated arterial insufficiency of the upper extremity. Buerger's disease of the lower extremity is indeed frequently associated with arterial insuf-

ficiency of the upper extremity. In our experience, however, arteriosclerosis is by far the most common cause of this condition in persons over 40. The presence or absence of disease in the upper extremity in itself is not a differentiating factor, although when considered with the age of onset, it can be highly significant. For example, the nondiabetic patient under 40 with arterial insufficiency in both upper and lower extremities is likely to have Buerger's disease, whereas any patient over 40 is unlikely to have Buerger's disease. In doubtful cases, however, and in all cases in which occlusion in the ilio-femoral region is suspected, arteriographic studies are essential not only to confirm the diagnosis but also to demonstrate the presence or absence of a patent segment of artery distal to the occlusion.

METHODS OF EXAMINATION

By means of the physical examination the suspicions of arterial insufficiency can usually be confirmed. Obvious signs of severe arterial insufficiency such as ulceration, gangrene, rubor and atrophy are usually easily detectable on inspection. In patients with less severe involvement such obvious signs of arterial insufficiency may be absent. Significant findings, however, can be readily elicited by two relatively simple maneuvers which deserve emphasis not only because of the significant information they may provide but also because experience has shown that they are often overlooked or inadequately performed. The first of these is elevation of the extremity to demonstrate blanching followed by depression below the heart level to demonstrate slow venous filling and slowly developing redness. The primary source of difficulty in this test is lack of effort or forgetfulness on the part of the examiner. The other maneuver is palpation of the peripheral pulses. Femoral pulses, when present, offer little or no difficulty; however, popliteal and pedal pulses, even when normal, are sometimes difficult to elicit. The relative inaccessibility of the popliteal artery, particularly without thigh muscle relaxation and variation in the location of the pedal arteries, demands some special knowledge in the examination for the respective pulses.

Popliteal Pulse

The popliteal artery is most accessible to palpation in the popliteal fossa directly behind the patella. The artery at this

level is located midway between the medial and lateral hamstring muscle tendons and is covered only by skin, fascia and loose fatty areolar tissue. Ordinarily, its pulsations are well transmitted from this region. Muscle contraction and extension of the lower leg places the tough popliteal fascia under tension so that the pulse is difficult to feel. Accordingly, when this artery is examined for pulsations, the hamstring muscles should be relaxed and the knee slightly flexed. This can be accomplished by either of two technics. First, with the examiner facing the patient, who is supine, the knee is grasped between both hands and lifted slightly above the table to about 15° flexion. During this maneuver the finger tips of both hands are placed in the space between the hamstring tendons and, if the knee is flexed and relaxed, pulsations can be felt in the popliteal artery. The second maneuver that facilitates detection of this pulsation consists of placing the patient in the prone position and flexing the knee about 90°. The popliteal fossa is thus relaxed and pulsations are easily detected by palpation over the course of the artery.

Dorsalis Pedis Pulse

The dorsalis pedis artery is the pedal extension of the anterior tibial artery and in 90% of patients it is located just lateral to the extensor tendon of the big toe (extensor hallucis longus). In the remainder of patients it may be located anywhere between this point and a line drawn down the foot from the fifth toe to the lateral malleolus. In order to palpate for this pulse, it is recommended that the examiner, facing the patient, grasp the foot between thumb and fingers of the contralateral hand so that the thumb extends across the sole and the fingers spread out across the dorsum of the foot. The pulse is easily located in this position by shifting the four finger tips about the dorsum of the foot after gentle dorsiflexion of the foot to relieve tendon and arterial tension.

Posterior Tibial Artery

There are at least two consistent landmarks for the posterior tibial artery at the ankle. Immediately posterior to the lateral malleolus, one is halfway between this structure and the medial edge of the Achilles tendon. The other is immediately under the sustentaculum tali between the malleolus and the sole of the foot. The easiest, most satisfactory method

of examinaion for this artery is to face the patient and grasp the ankle with the contralateral hand so that the thumb extends over the lateral aspect of the ankle and the finger tips of the other four fingers fall in the region of the posterior tibial artery. Slight dorsiflexion and external rotation with the other hand, combined with gentle palpation, greatly facilitate the location of this pulse.

Although the diagnosis of arterial insufficiency as well as the site of occlusion may be made by means of the physical examination in most cases, several specialized examinations may be necessary in some in order to confirm the diagnosis and select candidates for operation. These tests have also served as an objective means of evaluating results of operation. The ones most useful in clinical management are aortography and femoral arteriography. Plethysmography and oscillometry have been employed primarily for investigative purposes and are not considered essential in the clinical management of these patients.

Aortography

If visualization of occlusions in the aorta and iliac arteries is desirable, the contrast medium must be injected into the aorta above the occlusion. In order to be certain that the injection is placed above the disease and to prevent direct injection into a major visceral arterial branch, the needle must be inserted opposite the twelfth dorsal vertebra. Since the occlusive lesion may extend up to the origin of the renal arteries and since direct injection of contrast medium into the renal artery usually causes suppression of renal function, the site of injection must be above this level. The superior mesenteric artery and celiac axis arise only a few centimeters above the renal arteries, and although reports of damage from direct injection of these arteries are rare, this should be avoided; consequently, the twelfth dorsal vertebra is the recommended site.

A recent review of the complications associated with aortography revealed that most serious complications result from improper selection of the type and dosage of contrast medium. Inorganic iodides appear to be considerably more toxic than the organic iodide compounds, and it is recommended that only the latter be used.

Renal damage is the commonest serious complication. In

all reported instances of this complication either inorganic iodides in small repeated doses or excessive doses of organic iodides were used. This problem was investigated in our laboratory, and by means of detailed differential renal function studies it was shown that kidney function is not altered in the human by the intra-aortic suprarenal injection of 25 cc. or less of 70% urokon® sodium. On the other hand, significant transient reduction in renal function occurred in approximately 50% of the patients in whom 35 cc. or more of 70% urokon® sodium was used. Aortography was performed on approximately 200 of our patients, 25 cc. or less of 70% urokon® sodium being used with only one significant complication, which was temporary nonfunction of the right kidney following direct injection of the right renal artery. From these observations it would appear reasonable to assume that 70% urokon® sodium in doses not exceeding 25 cc. is safe for translumbar aortography, and by proper utilization of equipment the entire abdominal aorta and the peripheral arteries in the lower extremity can be visualized by one such injection. Other reported complications, such as paraplegia and hemorrhage, on analysis appear related to errors in selection of type and dosage of contrast medium and in the level and technic of injection.

On our service, aortography is performed in the Radiology Department on anesthetized patients on an ordinary x-ray table; however, all the respiratory anesthesia services of an operating room are available in this special x-ray room. Anesthesia is necessary to control motion of the patient as well as the severe pain associated with the procedure. This method appears justified, since no serious anesthetic complication has occurred in over 350 of these examinations. The patient lies on a thin box placed on the x-ray table. This box contains a 14-inch by 36-inch cassette with a built-in grid which is slightly wider and longer than the cassette. Consequently, the exposable area extends from just below the nipples to a point about 6 inches beyond the knees. Within the box and located between the x-ray film and the patient is a second tunnel for the shield. This is a thin 14-inch by 18-inch stainless steel plate mounted on rollers. The purpose of this shield is to permit exposure of the aorto-iliac and femoro-popliteal segments at different intervals after one injection of contrast medium and without unduly increasing the exposure time. The total exposure time is one second. We consider the longer

exposure times over a course of months on a busy vascular service to be not only entirely unnecessary but hazardous.

With the patient prone and after the midback has been aseptically prepared and draped, a 7-inch #17 thin needle is inserted into the aorta opposite the twelfth dorsal vertebra. It is important, however, to pierce the aorta only once, since those few reported instances of hemorrhage following this procedure have followed multiple aortic punctures. The recommended dosage of 70% urokon* sodium ranges from 10 cc. to 25 cc., depending on the size of the patient and the extent of occlusion. Smaller patients and those with complete and extensive occlusions will, of course, require the smaller doses. The medium is injected from a 50 cc. syringe which is connected to the needle by a flexible tube. The large syringe permits rapid flow of dye and the flexible tube permits motion of the operator's hand during injection without disturbing the position of the needle. The tube also permits injection from behind a shield that protects the operator.

The steel plate in the box shields the film under the femoropopliteal segment at the outset of the injection. As the last cc. of medium is injected, the first exposure is made from a source of x-ray energy located 54 inches above the film and centered over the buttocks. Immediately following this, the steel plate is pulled cephalad to shield the exposed aorto-iliac segment and, after appropriate delay, a second exposure is made with the source of energy in the same place as the previous exposure. The interval between exposures is estimated on the basis of the degree of collateral circulation present. This interval is approximately 6 seconds in patients with good collateral circulation and 10 to 15 seconds if cutaneous ischemic lesions are present. This technic permits complete study of the arterial channels in the area of disease and determination of operability with one injection of a safe dose of contrast medium.

Femoral Arteriography

Even though aortography has been extremely helpful in the treatment of aorto-iliac occlusions, it has been absolutely essential only in patients with partial obstruction of blood flow, in order to localize the lesion precisely. The relative unimportance of aortography is evident by the fact that in all 253 patients in our series treated for occlusion of the aorta

or iliac arteries, a patent distal segment to which a graft could be attached was found either in the pelvis or groin. Femoral occlusions, on the other hand, have not always been as localized and because of the diffuse nature of some of the

FIG. 6.—Complete segmental occlusion of the superficial femoral artery with patent popliteal artery below the occlusion. Such a patient is an ideal candidate for operation.

lesions at this level, femoral arteriography has been necessary in all such cases. Although the diagnosis can usually be made on a clinical basis, operability cannot be determined without arteriography. A patient with mild claudication and good circulation at rest may not have a patent segment distal to the occlusion large enough to which a graft may be attached, whereas a patient with serious ischemic changes severe enough to suggest amputation may have a localized operable

lesion. Although femoral lesions are not always localized, operable lesions have been found in over 75% of the patients we have studied.

Since the preoperative problem in femoral occlusion is to determine the presence or absence of a distal patent arterial segment large enough to permit anastomosis, this is the only arterial segment that needs emphasis in the arteriogram; consequently, the facilities available in any radiology department are adequate for this study. With the patient lying supine on an ordinary x-ray table, a 14-inch by 18-inch cassette with grid is placed under the knee with the patella at the center of the cassette and the source of energy focused on the patella. A local anesthetic is used. General or spinal anesthesia is not necessary for femoral arteriography since the pain is only moderately severe, transient and localized. Adding procaine to the contrast medium does not prevent pain and in our experience all contrast media in equal concentration have produced the same amount of pain.

A #18 Cournand needle is inserted into the femoral artery and 15 cc. of 30% urokon® sodium is injected rapidly into the femoral artery. After injection, exposure is delayed 5 to 15 seconds, depending on the degree of collateral blood flow estimated as described for aortography. If a reasonably normal patent popliteal artery is found distal to the femoral occlusion, the lesion is operable (Fig. 6).

TREATMENT

Restoration of Blood Flow

The ideal treatment of arterial insufficiency of the lower extremities is immediate restoration of a pulsatile blood flow throughout the entire limb. The restored approximately normal circulation permits return of normal muscular activity and provides normal reparative powers for the extremity, particularly the feet. To accomplish this, treatment must be directed toward the occlusion itself. The recently acquired knowledge of the localized nature of the occlusion to vessels of relatively large caliber and the finding of a normal segment both above and below the occlusion have permitted application of certain direct operative approaches. These include thrombo-endarterectomy, excision and replacement by prosthesis or graft, bypassing the occlusion by means of a

graft or prosthesis which is sutured end to side both above and below the occlusion or a combination of these procedures (Fig. 7). The indications for these procedures are dependent on the location, extent and nature of the occlusive process.

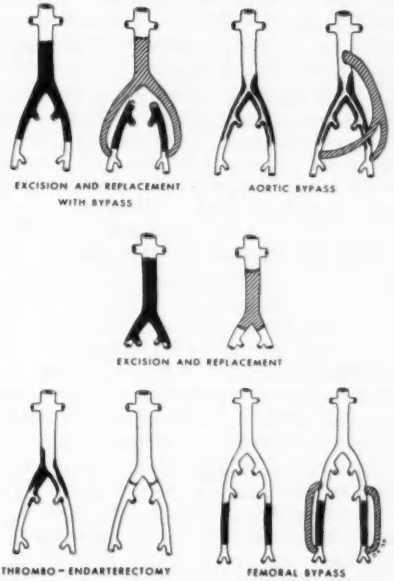

FIG. 7.—Various direct operative procedures employed in the treatment of segmental occlusions.

THROMBO-ENDARTERECTOMY.—Thrombo-endarterectomy is a procedure that entails actual removal of the obstructing lesion. As previously pointed out, the occluding atheromas are located primarily in the intima and subintimal layers of the artery, whereas the media and adventitia may remain relatively free of disease. Since there is a definite cleavage between the normal outer arterial layers and the diseased inner layers obstructing the lumen of the artery, the occlusion can be dissected from the artery and patency restored. The obvious advantage of this operation over others is the fact that the patient's own tissues are used rather than blood vessel

replacements. The thin endarterectomized vessel becomes lined by new healthy intima and surrounded by dense fibrous scar tissue. Consequent to these changes, aneurysm and occlusion do not occur if the operation has been adequately performed from a technical and anatomic standpoint.

Endarterectomy as performed by Dos Santos and associates was the first of the direct procedures to be used to restore a pulsatile circulation and, although striking improvement was obtained, this procedure has since been largely reserved for special circumstances. Experience with this procedure has indicated a higher incidence of operative failure than with graft operations and, most important, the preoperative ischemia is likely to be made worse in the event of failure. Consequently, there is risk of loss of limb in a significant percentage of the patients requiring operation. The explanation for these results lies in the fact that the operation is more extensive than is the graft procedure and the disease must be absolutely localized. Localization may be complete in many cases; however, this is a relative quality in a large number of patients and, because of the diffuse nature of the disease, complete endarterectomy as required to prevent complications cannot be accomplished. Such ideal circumstances are not necessary for the graft operation; consequently, the small margin of safety inherent in endarterectomy has limited its applicability to those patients whose lesions are localized to a segment of a large vessel less than 6 cm. in length. In view of these considerations, we have reserved this procedure for short, discrete lesions involving either the terminal aorta or the iliac arteries.

BLOOD VESSEL REPLACEMENT OPERATIONS.—All procedures other than endarterectomy directed toward restoration of an immediate pulsatile blood flow utilize blood vessel replacement. The operations differ according to the type of graft used and the technics by which it is inserted. Each of these variables has a bearing on the problem, and for this reason analysis of available experience with each seems desirable.

Vascular Substitutes.—The first vascular substitute employed successfully in patients was the aortic homograft more than eight years ago. Both aortic and arterial homografts, regardless of the manner of preparation and preservation, have continued to function most satisfactorily. The characteristics of these homografts are identical to those of the vessels being replaced; consequently, the technical and functional

performance of arterial homografts has been highly satisfactory.

The main problem relating to vascular substitutes has been the availability of homografts. The technical and legal factors involved in procurement, preparation and preservation are such that homografts are not generally available to meet the needs of replacement in many communities, and this problem is likely to worsen as the demand becomes greater in the future. Autogenous vein grafts have been used with only limited success in the extremities because of the general lack of a vein of suitable length and caliber as well as the added extent of operation required in its procurement. Such grafts have not been available for aortic replacement because the vena cava cannot be sacrificed without producing undesirable sequelae. Grafts from the pig, sheep, cow and horse have all proved to be unsatisfactory. Although these grafts may function for a time, disintegration begins early and surpasses host replacement so that aneurysms develop with consequent rupture or thrombosis.

The greatest effort expended in the development of vascular substitutes has naturally been in the field of synthetic materials and many substances have been employed both clinically and in the laboratory. These include ivalon, nylon, orlon and dacron. During the past few years we have replaced segments of the aorta and peripheral arteries of 144 patients with one of these four types of prosthesis. Blood flow was restored in all patients having aortic replacement but similar success with prostheses in restoration of circulation in the peripheral arteries has not been obtained. The crimped nylon tube developed by Edwards and Tapp has been the only prosthetic used in which the results in the peripheral vessels have approximated those from arterial homografts.

Technically none of these tubes is entirely satisfactory, although the functional results have usually been good. The plastic impregnated orlon tubes are too stiff and inelastic, characteristics which greatly increase the technical difficulties of insertion into the aorta and make them unacceptable for use in the peripheral arteries. The ivalon tube has the same inelastic quality but to a lesser extent, and it is difficult to pull the suture through it. Another disadvantage of this substance is the apparent difficulty in getting a purified substance because those tubes used in the leg have not only become thrombosed early but sterile inflammatory reactions

have occurred around some of them. The knitted orlon tubes have the same undesirable qualities of inelasticity, resistance to passage of the suture and fraying. A disadvantage common to all available ready-made prostheses is the lack of adaptability to varying sizes of host vessels and lack of secondary branches (Fig 8).

The Edwards-Tapp tube has been the most satisfactory prosthetic arterial replacement in our experience. With use of the crimp principle, an extremely flexible tube has been made that can be inserted easily without kinking (Fig. 10). Heat-melting of the ends has minimized fraying and the resistance of the material to the passage of a suture has been reduced to a satisfactory degree. Bleeding through the walls of the tube is controlled reasonably well by preclotting in the patient's own blood, and bleeding through the suture holes, although considerably greater than in a homograft, is not excessive. The early results with use of this tube have approximated those of arterial homografts and in the peripheral arteries this tube has been the only satisfactory prosthetic. Its applicability and supply in varying sizes make its use possible in most lesions. At present it cannot be used in instances in which branches other than the common iliacs are needed and in abdominal lesions in which the diameter of the proximal host aorta is significantly greater than that of the tube. A structural defect still present in the bifurcated tube is the tendency of the iliac segment to fray and become narrowed when under the desired tension. These are technical defects which should be corrected with further refinements in manufacture. In view of this early technical and functional performance of the Edwards-Tapp tube, which closely approximates that of arterial homografts, it is conceivable that with continued improvement in manufacture and design, these tubes might supplant the arterial homograft.

Technic of Replacement Insertion.—The vascular replacement may be substituted for the occluded segment by one of several technics. In the first, the occluded segment is completely excised and the replacement is sutured end to end to the host vessel (Figs. 9 and 10). This is usually the procedure of choice in the terminal aorta and common iliac arteries in cases in which the mural atherosclerotic changes about the bifurcation are extensive and destructive and from which arise collateral channels that are relatively insignificant. This is demonstrated by the fact that it was employed

FIG.
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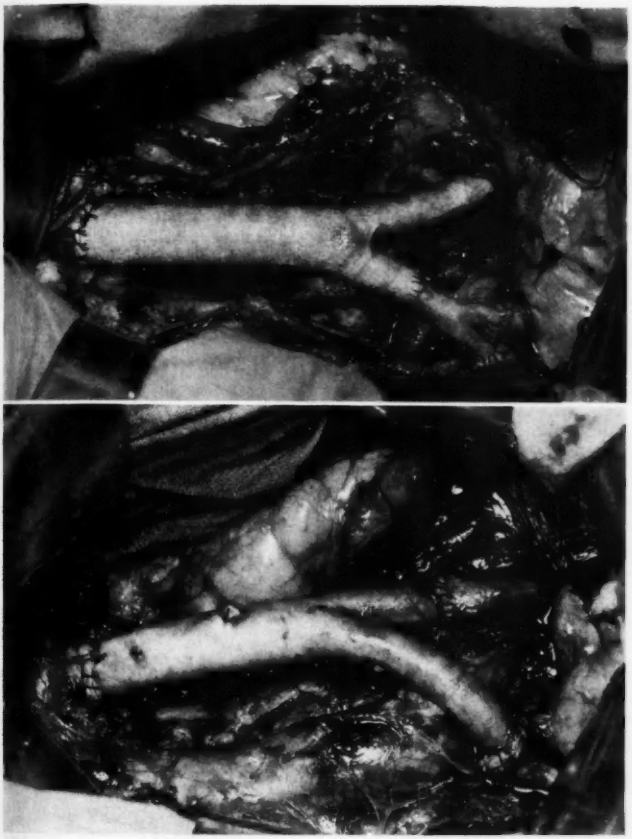

FIG. 8 *(above)*.—Compressed polyvinyl sponge (ivalon) prosthesis used to replace distal aorta and common iliac arteries. Right common iliac artery bifurcation replacement required use of an arterial homograft.

FIG. 9 *(below)*.—Reconstituted lyophilized aortic homograft used to replace the resected aortic bifurcation and common iliac arteries.

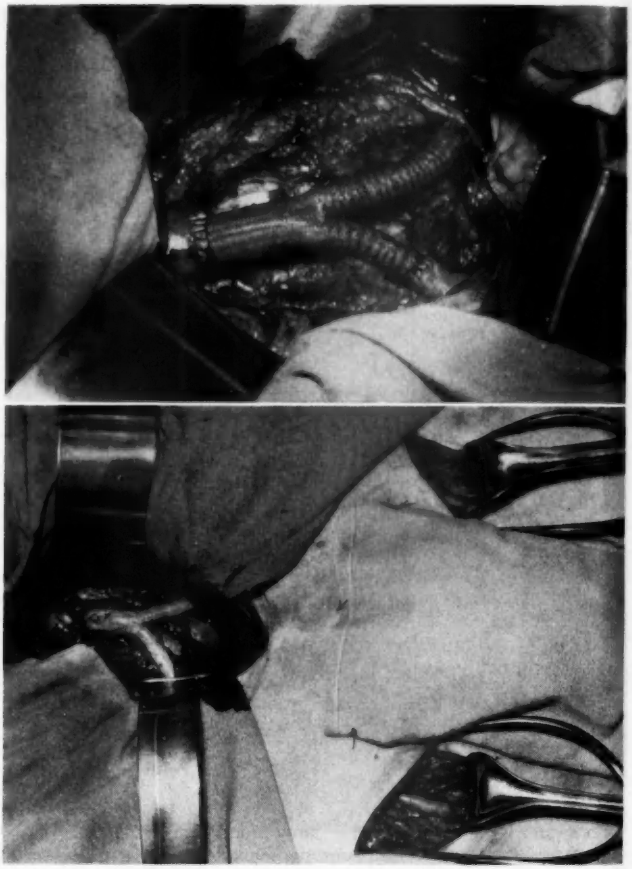

FIG. 10 (*above*).—Woven nylon prosthesis (Edwards-Tapp) replacing resected aortic bifurcation and segments of iliac arteries.

FIG. 11 (*below*).—Reconstituted lyophilized aortic bifurcation homograft bypassing an extensive occlusive lesion of both iliac arteries and the distal aorta. The graft has been sutured end to side to the abdominal aorta proximal to occlusive process and end to side to both common femoral arteries distally.

in 113 cases in this series (Table 2). Although in most of these cases partially organized thrombus occluded the aortic lumen for variable distances up to the origin of the renal arteries, it was possible by endarterectomy to remove this segment of the occluding process and thus preserve an adequate margin of aorta immediately below the renal arteries to permit anastomosis to the graft. A similar occlusive process resulting more from plaque formation than from

TABLE 2.—PROCEDURES USED IN TREATMENT OF OCCLUSIVE DISEASES OF AORTA

PROCEDURE	NO. CASES
Excision with graft replacement	113
Excision with graft replacement and bypass	47
Bypass with graft replacement	42
Thrombo-endarterectomy	51
Total	253

thrombus may also be found in the common iliac arteries below and usually extends down to the bifurcation of these vessels. It is usually possible to remove this intraluminal occlusive process by endarterectomy and thus permit anastomosis of the common iliac segments of the graft to the common iliac arteries.

In some cases of aorto-iliac disease, however, in which the occlusive process is extensive distally and involves virtually the entire iliac vessels, thrombo-endarterectomy of these vessels has been found less effective and associated with a high incidence of subsequent thrombosis. Under these circumstances the bypass principle is employed after excision of the occluded segment of the terminal aorta and bifurcation as in the previous operation. This is done by end-to-end anastomosis of the aortic end of a bifurcation aortic homograft or comparable plastic tube to the proximal end of the host aorta and insertion by means of an end-to-side anastomosis of the iliac arms of the graft to a patent segment of the distal arterial bed, such as the external iliac, femoral or even the popliteal artery. This type of procedure was employed in 47 cases in this series (Table 2).

Under still other circumstances, this bypass principle, as originally proposed by Kunlin, may also be employed without resection or endarterectomy of the occluded segment. By this means, the graft or plastic tube is attached by an end-to-side

anastomosis to a patent segment of the vessel above and below the occlusive lesion, thus completely bypassing the obliterated area (Figs. 11 and 12). The rationale of this procedure lies in nature's response to arterial occlusion, which is the development of collateral vessels around the area of obstruction. Thus, it consists essentially of the addition of a large collateral vessel around the occluded segment but equal in size to the host artery. The essential requirement in the successful application of this procedure is the presence of a good peripheral outflow bed, which may be ascertained by

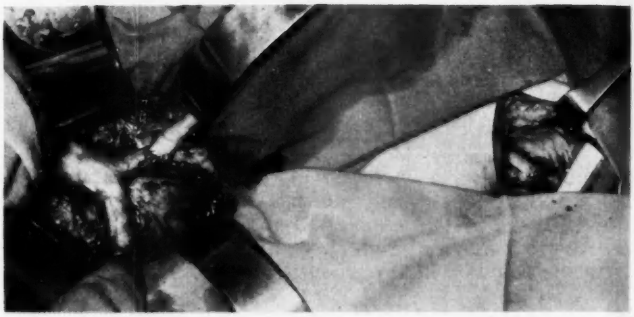

FIG. 12.—Reconstituted lyophilized iliofemoral homograft inserted end to side to the common iliac artery above and the common femoral artery below an extensive occlusion of the left external iliac artery.

the arteriogram. Since the procedure can usually be performed through two small incisions to expose patent segments of the host artery above and below the occlusion, it has considerable advantages in minimizing operative trauma and injury to surrounding structures and particularly to existing collateral vessels (Fig. 13). This is especially desirable in certain types of cases such as those in older patients, those with relatively long occluded segments, and those in whom recurrent segmental occlusion has taken place following previous operative intervention. The avoidance of injury to existing collaterals is a particularly important feature of this procedure and has been a source of reassurance in considering operation on patients with extensive peripheral occlusive disease in whom there may be some doubt concerning the adequacy of the peripheral outflow bed. This has

FIG. 13.—*A*, Occlusion of the distal superficial femoral and proximal popliteal artery with a patent distal segment of popliteal artery.

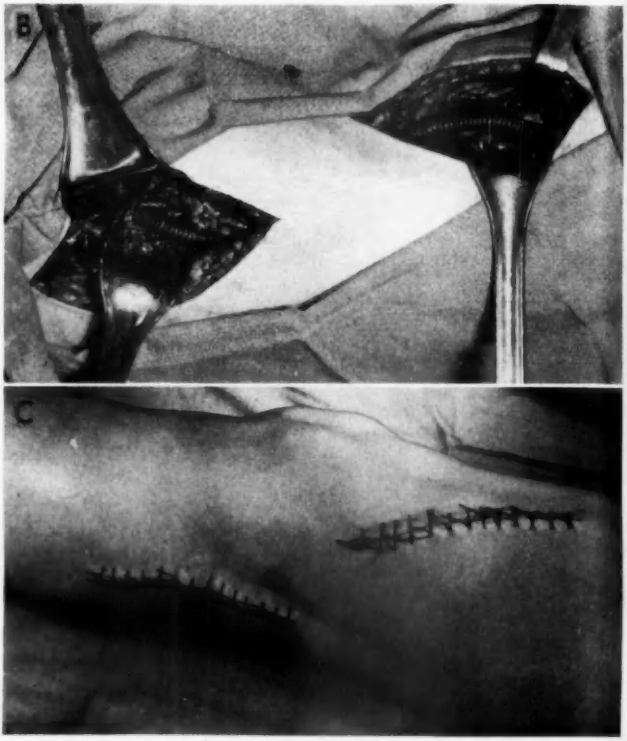

FIG. 13 *(cont.).—B*, woven and crimped nylon (Edwards-Tapp) tube inserted end to side to the superficial femoral artery (right) and popliteal artery (left) above and below a segmental occlusion. *C*, incisions used in operation.

been well demonstrated by the fact that among the peripheral lesions amputation was not precipitated by operation in any of the 153 cases in which we have applied this principle, whereas 5 amputations were necessitated in the 30 cases in which endarterectomy or excision and graft replacement were employed. An additional desirable feature of this operation is that it permits treatment of the most extensive occlusions without significantly increasing the actual extent of the operation. We now have a fairly large number of patients with grafts extending from the aorta just distal to the renal arteries down to the popliteal arteries behind the knee. Because of these considerations we have become convinced that end-to-side bypass procedure is the operation of choice for peripheral occlusion as well as certain types of the more extensive lesions of the aorto-iliac segments.

The third type of operation by which a graft or prosthetic substitute can be inserted to replace the occluded artery is one in which the diseased segment of artery is excluded. This is essentially similar to the previous bypass procedure but with the slight modification that the patent segments of the host artery immediately above and below the occlusion are completely transected and the graft inserted by end-to-end anastomosis. On the basis of our experience, this modification of the bypass principle seems to have no advantage and may actually be associated with some disadvantages by possible injury to collateral vessels. Accordingly, it is not recommended.

Lumbar Sympathectomy

Although immediate restoration of circulation by direct measures is the most effective method of treatment for arterial insufficiency, the pathologic features of the disease in a certain proportion of patients, particularly those with diffuse peripheral lesions, do not permit its application. Admittedly, sympathectomy may not completely relieve symptoms, but in some cases it may be of considerable supportive value. Its rationale lies in release of vasoconstrictor tonus and the consequent production of the maximal degree of vasodilation in the remaining unobstructed arterial bed. It thus produces an increase in the volume of the local vascular bed and consequent improvement in the local circulation. To be sure, this takes place primarily in the skin and not in the

muscular components of the extremities, but this is a desirable objective, since deficiency in cutaneous circulation of the foot and toes constitutes a major threat to patients with arteriosclerotic peripheral vascular disease. Gangrenous changes occur first in the skin of these parts; this occurrence, rather than intermittent claudication, is the most common cause for amputation. Accordingly, improvement in blood flow through the skin with the production of a dry, warm foot assumes major importance.

We now believe that lumbar sympathectomy is indicated in two specific groups of patients. The predominant group are those selected from the ones in which direct operative measures are not applicable, namely those in which no patent segment is demonstrable at any level down to the popliteal artery. All such selected patients have mild to moderate but rarely severe ischemia and by specialized vascular studies (plethysmography, oscillometry and skin temperature studies) show considerable collateral flow and measurable vasoconstrictor tonus. Patients having minimal collateral flow and absent vasoconstrictor tonus are rejected for sympathectomy. The second group of patients who would benefit by lumbar sympathectomy consists of those whose major arterial occlusions were satisfactorily treated with a graft but who have either secondary narrowing and occlusion in the small distal arteries or increased sympathetic activity in the lower legs and feet. The results of sympathectomy under these circumstances have generally been satisfactory.

Local Supportive Measures

A relatively small group of patients with arterial insufficiency from femoral occlusions will have diffuse peripheral occlusions and, in the absence of an operable patent distal segment, will not be candidates for the direct operative procedures. By the criteria mentioned, they also will not be candidates for lumbar sympathectomy. Since the amount of collateral blood flow is small, a moderate to severe degree of ischemia will be present in most of these inoperable cases. Many of these patients are destined for early amputation but frequently their extremities can be salvaged by vigorous conservative measures, consisting of limitation of activity, local care of the feet, Buerger's exercises and symptomatic relief of discomfort in the extremity.

Limitation of activity, of course, reduces the demand for circulation and lowers the risk of trauma to the ischemic extremity. Maximal limitation of activity (complete bed rest) may be desirable. The head of the bed should be elevated six to eight inches so as to maintain the lower extremities in a dependent position. This position is frequently the one most comfortable to the patient, since it maintains passive congestion of the feet and allows maximal utilization of the circulation present.

Local care of the feet in all patients with arterial insufficiency and particularly in those whose circulation cannot be restored is a most important yet frequently neglected consideration. Minor trauma and ordinarily insignificant infection are poorly tolerated by ischemic extremities and such accidents usually precipitate amputation. Consequently, extreme care must be exercised in the prevention and treatment of such lesions. The feet should be washed daily with a bland soap and slightly warm water, and then completely dried, especially between the toes, with a soft cloth. Flexibility of skin to prevent fissuring should be maintained by daily application of lanolin and interdigital ventilation maintained by placing nonwettable lamb's wool between the toes. When the patient is in bed, his heels should be protected from pressure and friction burns. Foot boards or other methods of elevating the bed covering will prevent pressure and frictional injury to the toes. This equipment should project from the foot of the bed, since metallic cradles placed in the bed with the patient are constant sources of trauma. Open lesions should be cultured and the appropriate antibiotic determined by sensitivity tests so that the ideal bacteriostatic agent can be prescribed.

Passive congestion of the extremities is maintained to some degree throughout the day and intermittently controlled by Buerger's exercises unless the patient has an infected lesion. As is well known, these exercises consist of alternating passive congestion with complete venous drainage of the extremities. The time intervals are calculated on the basis of the time required for the foot to become blanched on elevation as well as the time for complete venous filling on dependency. These intervals vary somewhat, but in most patients the legs are elevated above the level of the heart for one minute. This is followed immediately by hanging the extremities over the side of the bed for four minutes, during

which time the patient exercises the feet. This is followed by a five-minute rest period with the limbs lying flat in bed. This cycle is repeated ten times three times daily. Pain is

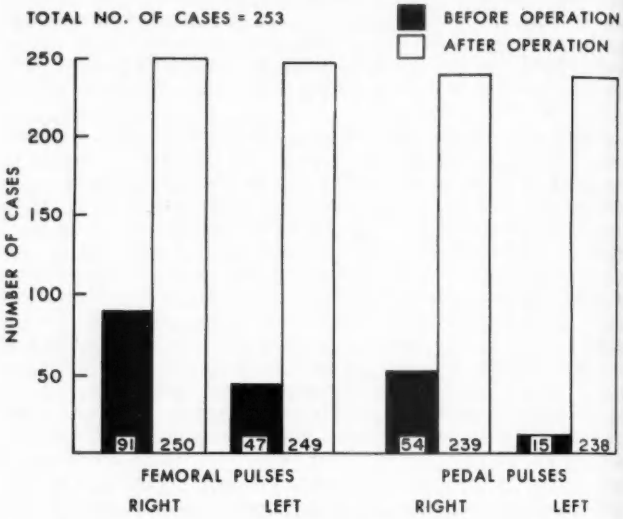

FIG. 14.—Results of operations for arteriosclerotic occlusive lesions of the aorta.

controlled by a combination of oral use of alcohol, mild narcotics and liberal vitamin administration in an effort to minimize peripheral neuropathies.

SELECTION OF PATIENTS FOR OPERATION

The anatomic and pathologic requirements for operation have already been discussed and at this point it is only necessary to emphasize again the fact that all aorto-iliac occlusions are operable and, although the majority of femoral occlusions are operable, selection of the latter cases can be based only on the demonstration of a patent distal segment by arteriography. Neither the degree of circulatory impairment nor other clinical signs are of help in the selection of

patients for the direct operative procedures. We believe that all patients with arterial insufficiency due to aorto-iliac occlusion and all with femoral occlusion in whom a patent distal segment is demonstrable arteriographically are candidates for operation except in the presence of advanced cerebral or cardiorenal disease. In such patients intermittent claudication alone is not an indication for operation, since the increased activity afforded by operation may not be necessary and may be actually contraindicated. On the other hand, in more advanced cases of ischemia threatening amputation, we consider operation to be indicated. Under these circumstances a restorative operation is substituted for amputation and not only are limbs salvaged, but the patients appear to respond better to such operations than to amputation. Compensated heart disease, hypertension and diabetes are definitely not contraindications to operation. This is evident by the fact that in the 436 patients treated in our series by one or more restorative operations almost one third had heart disease, about one half had hypertension and approximately one tenth had diabetes, but regardless of these complicating factors, the total mortality rate was only 2.9%. This mortality compares favorably with that resulting from sympathectomy or amputation. Age in itself is also not a contraindication to operation and although most of our patients were between 40 and 70, patients at both extremes of life have been successfully rehabilitated by restoration of circulation (Fig. 14, Tables 1 and 3).

RESULTS OF OPERATION BY THE RESTORATIVE TECHNICS

Our experience with these restorative operations for arteriosclerotic occlusive disease of the lower extremities includes a total of 436 cases. For purposes of discussion these cases have been divided according to the location of the lesion and the operation performed.

Occlusions of the Aorto-Iliac Segment

There were 253 patients with occlusions of the terminal aorta and iliac segments treated surgically. Since few patients were denied operation, this constitutes practically our entire experience with the diseases at this level. The ages and severity of occlusion in this group of cases are shown in Table 1.

The operations performed are shown in Table 2. Of the nine hospital deaths, three were due to renal failure, three to myocardial infarction, one to pulmonary embolism, and two to hemorrhage. Amputation was either not prevented or precipitated in five extremities. The circulation in almost all of the remaining patients was restored, as evidenced by the ap-

TABLE 3.—Summary of Treatment of Peripheral Arterial Occlusive Lesions by Use of Grafts or Arterial Prosthetics

Operation	Occlusion		Patent Grafts	
	Location	Number of Ops.*	Number	Per Cent
Excision and graft	Iliac	18	17	95
	Femoral	12	9	75
End-to-side bypass	Iliac	68	67	98
	Femoral	85	75	88
Total		183	168	92

*Vascular prosthetics were used in 38 operations and arterial homografts were used in 145 operations.

pearance of previously absent pulses, relief of symptoms and rapid healing of peripheral ischemic lesions (Fig. 14). An interesting and somewhat unexpected result was the frequent improvement or relief of sexual impotence, particularly in the younger age groups.

Iliac and Femoral Occlusions

There were 183 cases with occlusion at this level and most of these were treated by the end-to-side bypass procedure (Table 3). Distal pulsatile circulation was successfully restored in 92% of these cases (Table 3). Regardless of the operation performed, greater success was obtained in the larger, more central iliac artery than in the femoral artery. The explanation for this lies in the fact that occlusions of the iliac artery are usually discrete and are less often associated with diffuse disease than are occlusions of the femoral artery. Occlusions of the femoral artery were successfully treated more often by the end-to-side bypass procedure than by excision and graft (Table 3). The circulation was made worse in

three unsuccessfully treated cases of femoral occlusion by excision and graft and in two by endarterectomy. All these subsequently required amputation. The circulation in the extremities of patients unsuccessfully treated by the end-to-side bypass operation remained unchanged. There were four deaths in this group, all from coronary occlusion.

The functional results in those patients in whom a pulsatile circulation was re-established were striking. Claudication, rest pain and pain in ischemic ulcers were immediately relieved. Ischemic ulcers and infected lesions of all types healed spontaneously soon after operation and, although such lesions were present in 20% of the patients, amputation was averted in all of them.

These patients have been periodically observed since operation and the good results obtained in the aortic and iliac segments have persisted even from the first operation performed over four years ago. The results in the femoral group have also continued to be good as long as two and one half years in some cases. In the latter group there have been four cases of recurrence, 18, 14, 11 and 4 months after operation. Study of two of these patients revealed graft thrombosis to be responsible for failure, but despite this the preoperative circulation remained unchanged. Grafts were successfully reinserted in both. In the other two patients, operation was performed to avoid amputation which was imminent because of the severe rest pain and large ischemic ulcers. A distal pulsatile circulation was successfully restored in both cases following which pain was relieved and the lesions healed. Graft thrombosis occurred in these patients 11 and 4 months after operation. However, recurrence of occlusion was evident only by intermittent claudication, since the cutaneous lesions remained healed. Therefore, even though operative success was not maintained, the extremity was saved.

SUMMARY

Arterial insufficiency of the lower extremities is due to arteriosclerosis in most instances and can be readily differentiated from thromboangiitis obliterans. Arteriosclerotic arterial insufficiency characteristically appears in persons over 40 unless precipitated earlier by diabetes, whereas thromboangiitis obliterans is a disease of youth, occurring in persons in the third and fourth decades of life. Arteriographic con-

firmation of the diagnosis is essential, since a pulsatile circulation can be restored in most patients with arteriosclerotic occlusions but rarely in those with Buerger's disease.

Pathologically, the arteriosclerotic lesion in most instances of occlusion is well localized and limited to the intimal and subintimal layers of a major artery, the vessel both above and below this region often remaining unaltered. Consequently, a pulsatile blood flow can be re-established, even in advanced cases, by direct attack on the occluded segment either by thrombo-endarterectomy, excision and blood vessel replacement or the bypass procedure. By proper selection of patient and procedure, peripheral circulation can be restored in most instances.

An analysis of our experience with these methods in 436 cases is presented. In this series there were 253 cases with occlusion of the aorto-iliac segment and 183 cases with occlusion of the ilio-femoral level. The end-to-side bypass procedure has proved to be the most satisfactory method of treatment for peripheral lesions. The treatment of choice for occlusions of the aorto-iliac segment depends on the circumstances found at operation. Accordingly, excision with graft replacement, excision and bypass replacement, end-to-side bypass or thrombo-endarterectomy may be employed.

Circulation was restored in over 90% of the 436 patients, and symptoms were relieved in all of the successful cases. Amputation was averted in approximately 20% of these patients. The operative mortality in this series was 2.9%. The good results obtained by these procedures have persisted up to four years after operation with a very small incidence of recurrence.

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